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Publication date:
2000

Link to publication in Tilburg University Research Portal

Citation for published version (APA):
van Beeck, N. M. J. P. (2000). *A New Method for Local Energy Planning in Developing Countries*. (FEW Research Memorandum; Vol. 796). Operations research.
http://dbiref.uvt.nl/iPort?previous=25&sessionid=212144709760&request=full_record&position=1&domain=Dome

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A New Method for Local Energy Planning in Developing Countries

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Introduction

The Need for Energy Planning

In general, any activity requires energy. Economic development –as a result of increased activity– is thus accompanied by an increase in energy consumption. This link is illustrated by Figure 1, which shows the evolution of both Gross Domestic Product (GDP) as a measure for economic activity and primary energy consumption over time for different countries.

Especially developing countries show a rapid increase in energy demand when economic activity expands, which, in recent years, is well illustrated by Thailand in Figure 1. Highly industrialized countries such as the United States and the Netherlands, however, are now more and more trying to unlink economic growth and energy consumption, forced in part by environmental problems such as CO_2 emissions. Potential measures for “unlinking” include, for instance, increasing the energy efficiency, or establishing a sectoral shift from industrial activity towards services. Regardless of the efforts, actual unlinking results are not apparent in Figure 1.

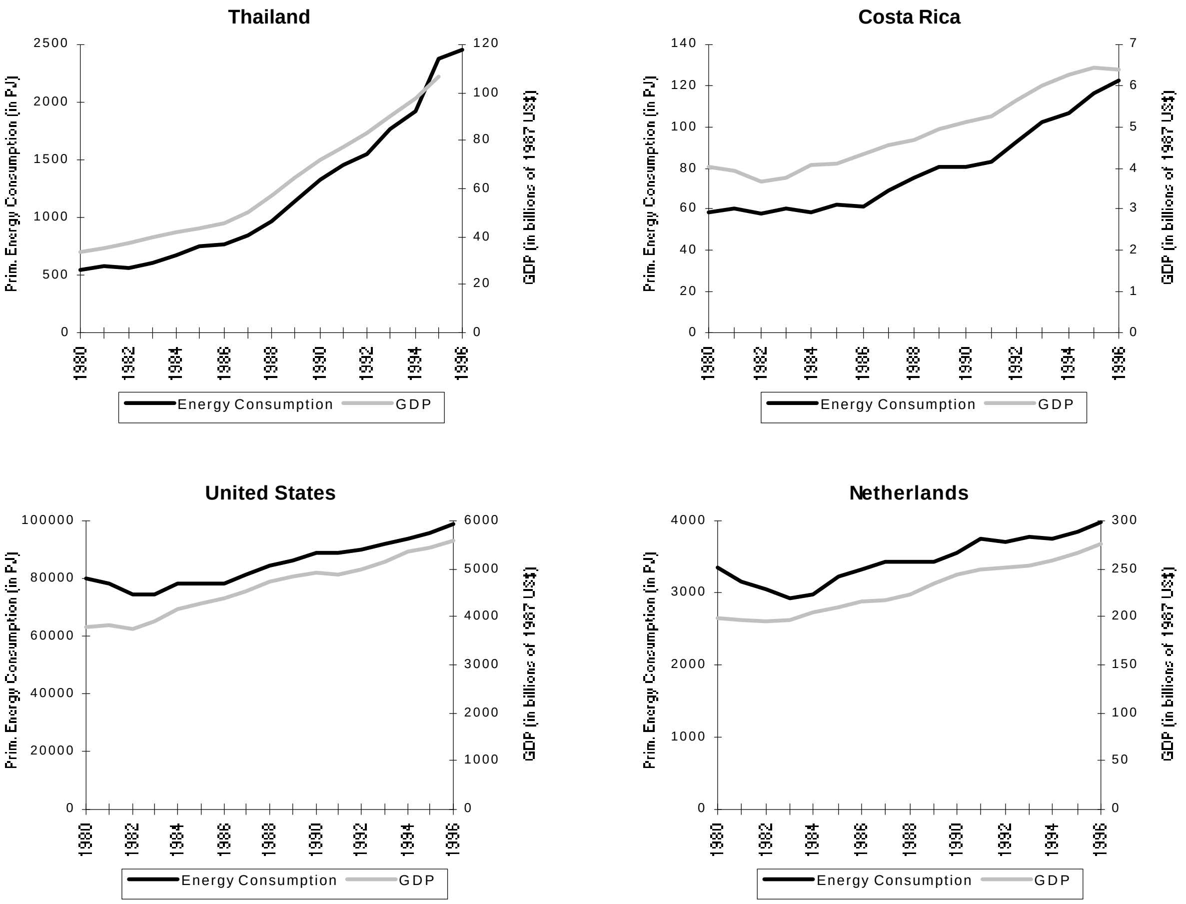

Figure 1. Gross Domestic Product (GDP) and Primary Energy Consumption for Thailand, Costa Rica, United States of America, and the Netherlands. Source: EIA (1998).

For developing countries it is important to ensure a sufficient energy supply in order to keep the momentum of growth. The already existing infrastructure will usually be insufficient to meet the increased demand, which will frustrate further economic and social development or may even stop development all together. However, making an ad-hoc decision on the energy infrastructure which later proves to be “wrong” (e.g., in terms of severe environmental impacts) will have serious consequences for a long period in the future. The development of an energy infrastructure involves irreversible investments and the infrastructure will be in operation for several decades, hereby imposing restrictions on future alternatives. With adequate energy planning a mismatch between demand and supply can be avoided. Also, energy planning offers the opportunity to keep the chance of making a wrong decision as low as possible. Energy planning is, thus, a crucial factor in the development process of a country.

Energy Planning as a Decision Making Process

In general, energy planning encompasses the establishment of goals, policies, and procedures concerning the supply as well as the demand of energy in the future. Planning can structure and support the concrete implementation activities in such a way that supply can always meet demand. In the context of this paper, energy planning is particularly focused on selecting appropriate energy supply systems or technologies[1]. The selection out of available energy systems should be seen as a decision making *process* rather than a fixed point in time, because it involves several subsequent steps which take time to be executed. In general, a decision making process can be divided into the following steps (see, for example, Carpenter (1987), and Georgopoulou et. al. (1997)):

1. Problem identification
2. Identification of relevant alternative options
3. Assessing and comparing options
4. Appraising options
5. Selecting an option

The next steps in line would be “implementing the decision” and “controlling and evaluation” but these are by definition not part of the planning process. In our case of energy planning, the identified problem is a foreseen shortage of certain forms of energy due to increased demand. The different energy systems that can supply the demanded forms of energy may not always be relevant, depending on the circumstances. For instance, a wind turbine that, in theory, is capable of providing sufficient electricity may not be a relevant option at a site where there is hardly any wind. The relevancy of energy systems thus depends highly on the context in which they are applied. Nonetheless, there will usually be several relevant alternative energy systems. The next step is then to assess the impacts associated with each option. Impacts commonly include technical and financial consequences, but may include economic, environmental, and social consequences as well. The comparison of the impacts of one system with those of another system may pose problems, especially in cases where there is no universal measure to which all impacts can be converted. The next step in the decision making process is appraising the options, followed by the last step, selecting one (or more) of the energy systems.

Constraints of Existing Methods and Models for Energy Planning

In this paper, a distinction is made between methods and models. In principle, both terms can mean the same but today, many models –especially bottom-up models[2]– are associated with computer programs. To avoid confusion, I distinguish between the conceptual framework for structuring the decision process on the one hand and the way things are calculated in detail (operationalized) on the other. I prefer to use the term *method* when referring to the conceptual framework and to use the term *model* for the (computerized) calculation procedure or format that is used to operationalize the method. Models, in this perspective, are thus part of a method. This is visualized in Figure 2.

Usually, the conceptual framework (method) consists of a transparent, logical structure that divides the decision process into several concrete steps. This way, different alternatives and their consequences can be systematically analyzed and compared in an explicit and efficient manner. The actual analysis and comparison are facilitated by the (computer) models.

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[1] The difference between an energy technology and an energy system is that a system encompasses every piece of equipment (cables, monitoring equipment, etc.) to make the technology work in practice.

[2] See Van Beeck (1999a) for a classification of energy models.

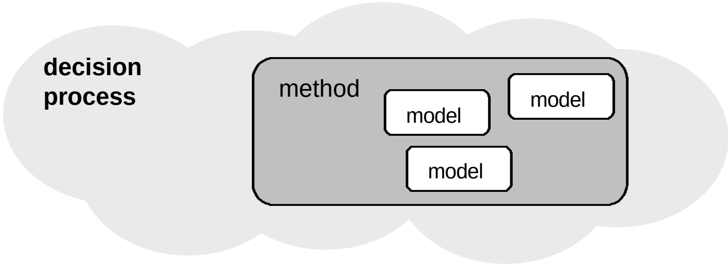

Figure 2. Distinction between method and models.

It is important to keep in mind that neither methods nor models can determine what action or decision is “good” or “best.” This depends on the (philosophical) viewpoint that is taken and the values that are accounted for. So what is “good” will ultimately be determined by the decision-makers. In addition, models can impossibly cover every aspect of reality. At best, models can give a solution for a (highly) simplified representation of parts of reality, but this says nothing about the desirability of that solution. Biswas (1990) and Van Beeck (1999a) both state several constraints associated with most methods and models existing today:

- *Context-related issues are not addressed*
  An important drawback of most methods and models is that many important political, social, institutional, and environmental issues –which are all highly context[3] dependent– are addressed in an unsatisfactory manner or not at all. A good example is that most engineering (bottom-up) models[2] still use financial efficiency as the main indicator for selection/ decision making. This is for a large part due to the fact that most context-related issues are not easily incorporated in a formal analytical framework. However, ignoring these context-related issues because they cannot easily be modeled may very well threaten the viability of the energy systems. Biswas calls this the “lack of understanding the decision making process” resulting in models that do not reflect the real situation which are therefore unacceptable to the decision-makers. Due to their emphasis on theoretical problems, many models cannot give answers to the questions actually posed by the decision-makers.

- *Data need to be expressed in monetary terms or at least be quantitative*
  Most models can only handle quantitative data of a specific type. Moreover, if financial efficiency is the sole indicator, all included aspects need to be converted into a monetary measure unit. Qualitative indicators cannot be addressed so aspects that cannot satisfactory be quantified (or monetized) are ignored.

- *Applicability to developing regions is low*
  Another drawback of may economic top-down models is that they often only use national parameters. Economic development is usually restricted to certain areas or regions within a country, but the specific characteristics of such a region are disregarded by the models. In addition, where most models inherently assume a succession of past trends, most conditions, especially in regions with rapid growth, are changing rapidly.

- *Technology treated as a black box*
  Often, especially with the “economic” models, the factor “technology” is represented in a highly aggregate manner, treating it as a black box. This makes a distinction between the various types of technologies often not possible, let alone a comparison of technologies.

- *Small-scale (renewable) energy systems are neglected*
  The models’ focus on national parameters results in a negligence of small-scale systems because the viability

3 The context in this case refers to the interrelated technological, economic, environmental, political, social, cultural, and institutional factors in a society or group.

of small-scale systems largely depends on local circumstances. However, small-scale energy systems may offer several advantages to large-scale systems such as flexible expansion due to their modular character, easy adaptation to local circumstances, step by step investment cost (putting less strain on budgets and foreign capital), and fewer transmission and distribution losses. Renewable energy systems, often small-scale systems, offer even more potential advantages such as the inexpensive or even free availability of resources that are locally available, and the environmental or social benefits that are often not taken into account in conventional (economic) analyses. So for a proper evaluation of the alternatives, small-scale / renewable energy systems should not be excluded beforehand.

- *Poor data availability and reliability in developing countries*
  Most existing models require considerable data to perform their analysis. Although the collection of data and the conversion into a unified (monetary) measure seems to be difficult and time consuming in every country, it particularly appears to be a constraint in developing countries. Biswas (1990) states that in developing countries many data concerning the energy infrastructure are simply not available. Moreover, poor or non-existent data management, inter-ministerial and/ or inter-institutional rivalry, unnecessary classification of data as secret or confidential combined with official apathy often ensure that the data that actually are collected are not easily available. Furthermore, if data are available, there is no guarantee that they are reliable as well. This lack of reliable quantitative data in developing countries poses a severe constraint on the use of any model.

The constraints mentioned above make existing methods less suited for local energy planning, especially in developing countries. In the next chapter we will discuss the outline of a new method for local energy planning in developing countries.

A New Method for Local Energy Planning in Developing Countries

Why a New Method?

As we discussed earlier, the basic purpose of designing a new method is to support decisions by providing a systematic, transparent, and efficient manner to select an option out of a limited number of alternatives. Therefore, the method can also be referred to as a decision support method. Our specific aim is to support energy planners in selecting an appropriate mix of energy supply technologies that can supply the increase in energy demand in a region that experiences rapid economic growth. Energy planners might include national and local governments, the energy utilities, construction companies, and such. Since the focus is on regions within countries, we will only look at small-scale systems (<< 100 MW). One advantage of focusing on the local level is that the implementation of the infrastructure also takes place at that level. So dealing with the local context likely reduces the chance of local resistance against the implemented technologies, a phenomenon that is not unknown for implementation of national plans.

Because existing methods and models are inadequate to accomplish our aim, we want to develop a new energy planning support method that is specifically designed for *developing countries*. One reason for this is that the energy infrastructures there are often not yet as developed as in industrialized countries, implying that the choice of energy technologies is not so much dictated by the already existing infrastructure. Also, the differences in economic growth between regions in a developing country can be much greater than in industrialized countries. Furthermore, many developing countries lack knowledge on available energy technology options, in particular the small-scale renewable ones.

Keeping in mind the constraints of existing methods and models mentioned in the previous section and applying the additional suggestions of Carpenter (1987, 18), the following guidelines are used for developing the new method:

1. The method must support the entire decision process from problem identification to the ultimate selection of an energy system.
2. The participants of the process must easily understand the method.
3. The method must allow for inclusion of context-related aspects. So the method must be able to not only handle aspects of a technical and financial nature, but also economical, environmental, and social aspects put forward by the participants.
4. The models of the method must allow for inclusion of qualitative data.
5. The method must be applicable to rapidly developing regions, implying that extrapolation of past trends is no longer valid.
6. The method must be able to differentiate between technologies, moreover, be able to compare them.
7. The method must be able to address fossil fuel energy systems as well as renewable energy systems.
8. To be generally applicable, the method must be flexible enough to adapt to data availability and local circumstances.

Furthermore, knowledge is a crucial factor in decision making, how much people know determines their range of alternatives. So besides providing a transparent, logical structure for the decision process of local energy planning, the method discussed here should also serve as an awareness-raising tool. This way, the energy planners' range of alternatives can be broadened by pointing out options and consequences that were unknown or seemed less evident at first. How these guidelines are applied in the new model is addressed in the next sections.

Outline of the New Method

In this section we will give a short outline of the new decision support method for local energy planning in developing countries. In the following sections, specific aspects of the method will be treated in more detail. The decision process begins with identifying the problem, which in general terms will be matching demand and supply for the short term as well as the longer term. This raises the first question, how much the demand for energy will be. In our method, this issue is addressed by analyzing the desired *energy services* (i.e., the purposes for which consumers use energy) and translating them into demand for certain energy forms such as heat or electricity or gas. With demand known, we can look at the options (including technologies and the resources they use) available for developing a new energy infrastructure that is able to supply this demand. Usually, an option will encompass more than one technology in order to supply the right forms of energy. A very important issue is then how these supply options can be compared. Remember that one of the guidelines for the new method was 'including context-related issues.' We propose to use the aims of the participants in the decision process (the so-called '*actors*') regarding a new energy infrastructure as a base for comparing the supply options *and* as a way to incorporate the context-related issues. For the actual comparison of the supply options, the actors' aims need to be translated into measurable *indicators*, which are used to assess the impacts of each technology option. The scores on each indicator (i.e., the impacts) can then be systematically compared. Note that the indicators may be qualitative, although a quantitative measure is preferred if available. The next step of the method consists of appraising each option, either with the help of special appraising models or through (internal) discussion. Because the aims of most actors will differ, the outcome of the appraisal step will also be different between actors. Therefore, these outcomes must be evaluated before a final mutually supported selection can be made. During the evaluation step, actors may want to make changes in the (priorities of) aims, or want to include other variations on supply options in the decision. In that case, the impact assessment and the appraisal step must be repeated and the new outcomes need to be evaluated once more.

The framework described above ensures that the choice for a particular (mix of) energy systems is well weighed. Moreover, we think that this procedure is more likely to result in a broad consensus for a selected option and subsequently a successful implementation than conventional methods. An overview of the method is presented in Figure 3, which clearly shows the distinction between the conceptual framework (the method) and the models that serve as calculation tools to facilitate the successful completion of each step.

A consequence of incorporating context-related issues in a method is that the *outcomes* will highly depend on the local circumstances and can therefore not be generalized easily. However, the *method* used to obtain an outcome will be generally applicable. The energy system, which is ultimately chosen, will be the most *appropriate* alternative within the given context rather than the "best" in terms of technical or cost performance. The context, the actors' aims, the energy services, and appropriate technologies are key issues in the new method for local energy planning in developing countries presented in this chapter. These issues will be discussed in more detail in the following sections.

So concluding we can say that the method (and its associated models) supports the energy planning process by:

I) Providing information on the relevant resources and energy technologies as well as the consequences of using them in a specific context.

II) Taking into account the aims of all relevant actors involved in the planning process as a way to incorporate context-related issues.

In order to test the practical applicability of the method and to assess the general requirements for the models we will make use of different case studies.

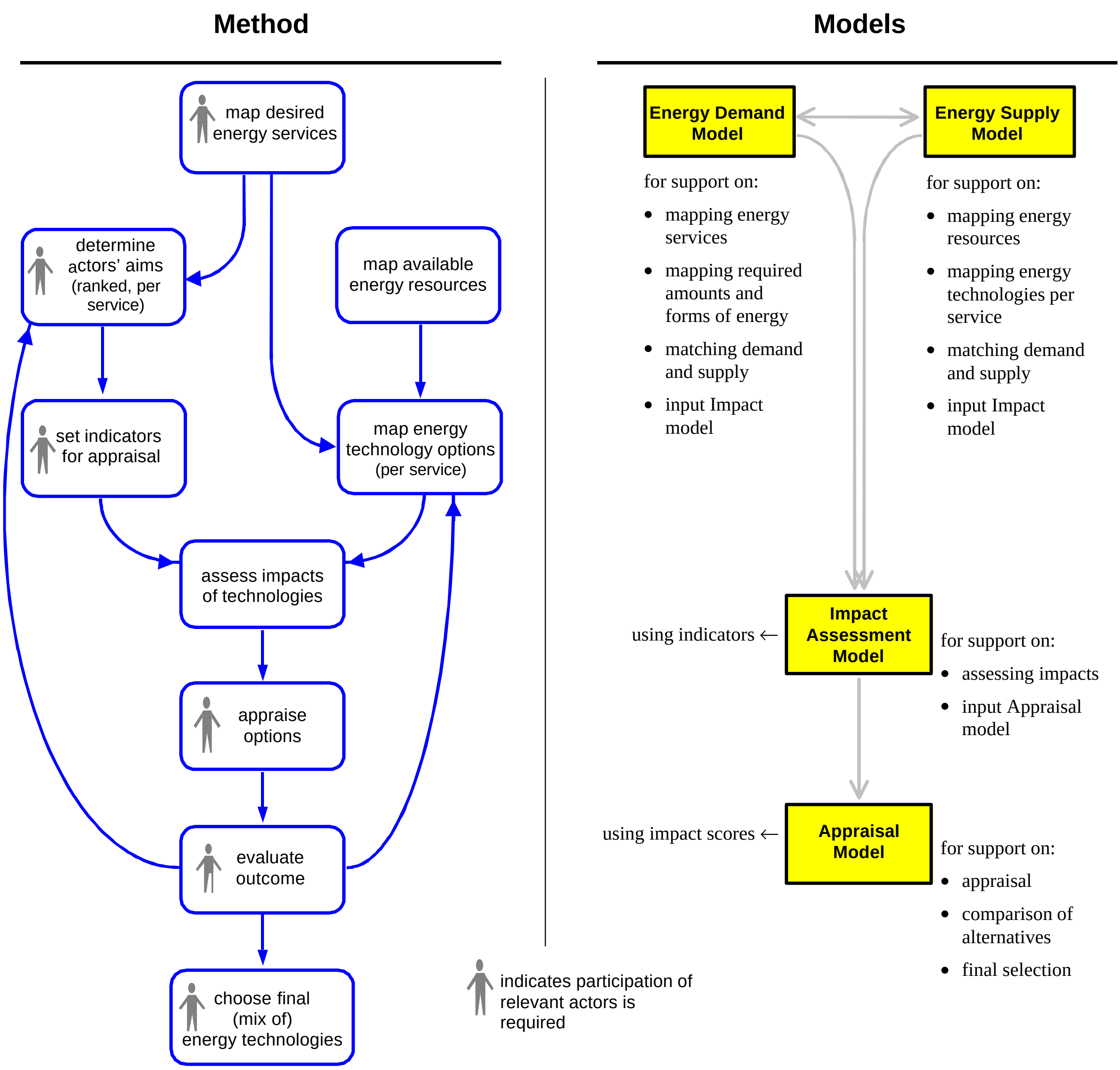

Figure 3. The steps of the decision support method for local energy planning and associated support models.

Energy Services

Starting point of the method are the *energy services* that consumers (households, firms, industries, etc.) desire. Energy services are the underlying reasons why consumers demand energy. For instance, people want electricity not because it is such a great form of energy, but because electricity allows them to watch TV or listen to the radio or put on the lights when it is dark. Similarly, people want heat to boil water or to heat their houses, and fuels may be used in cars to get from one place to another. Note that the term energy services should not be confused with a more economic oriented use of the term ‘service’ that utilities sometimes use to refer to the products they have to offer.

Each *energy form* (i.e., electricity, heat, fuels, or mechanical power) can usually provide more than one energy service. For instance, electricity can be used for lighting, cooking, and heating, while heat can be used for both cooking and heating, and fuels for cooking, heating, and transportation purposes and so on. Stated differently, the same energy service can be provided by different energy forms. The energy forms necessary to provide a service are generally the result of a conversion process of *energy sources*. These energy sources can either be depletable (such as crude oil, natural gas, coal, uranium), or renewable (such as wind, water, and the sun). Sometimes, a source can be both depletable and renewable, depending on how well it is managed. Biomass is a good example of an energy source that is only renewable if sufficient time is given for it to recover from harvests. Each energy source can provide different forms of energy depending on the conversion technologies used, but heat will always be one of the products.

So in our analysis, we will start with the desired energy services and work our way back towards the energy sources that can provide the proper energy forms for the services. This process from energy services to energy sources is illustrated in Figure 4.

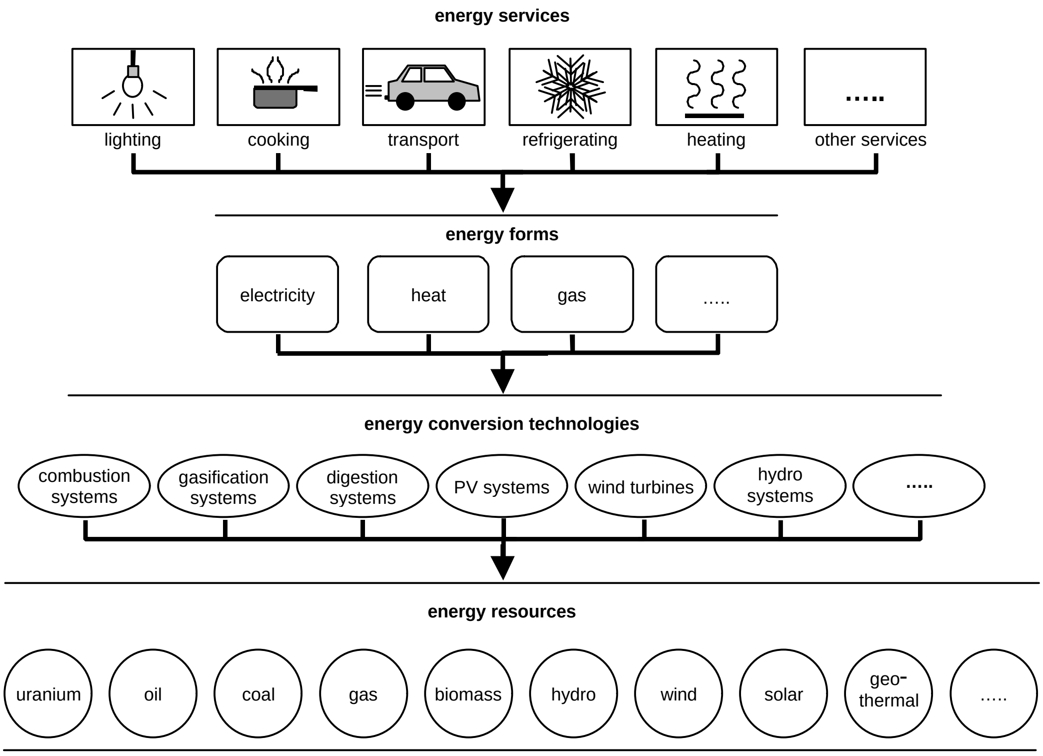

Figure 4. Structure of the ” energy services-to-sources” analysis.

Thus, the demand for energy is in fact the desire for certain energy services, which can be provided by different forms of energy. The energy forms, in turn, are a result of the conversion of energy sources using energy conversion technologies. Exactly these energy technologies are the central focus of our method because ultimately, we want to compare the different energy technologies that supply the proper energy forms to provide a desired service.

Aims of Actors

The next step in the decision support method for local energy planning involves the aims of the actors. Actors, in our case, are (groups of) people that are affected by the decisions regarding a new energy infrastructure *and* have the ability to influence the decision process. The local and national government are obvious examples of actors, especially in those cases where they play the role of the (co-)investor. The energy utilities are also evident actors, but interest groups promoting a clean environment (such as Greenpeace) can be an actor as well. A special group is formed by future generations. Although they are unable to influence the decision process, they certainly can be affected by the choice for a particular energy infrastructure. In our analysis, it is assumed that the aims of this group are represented by the government since the latter is the most designated actor to consider the long-term perspective. Similarly, other groups may also be represented by actors and sometimes, this may even be desirable or even necessary in order to limit the number of actors participating in the process. In theory, it is possible that only one actor applies the method, taking into account the presumed aims of others, although in practice this might turn out to be more complicated.

Each actor has its own aims regarding energy technologies. For instance, governments are concerned about whether choices are made in compliance with existing regulations and policies, while investors might value low costs, and consumers may value a cheap, reliable, and comfortable supply of energy. Even aesthetics can play a role. It is not unusual for actors to have conflicting aims or interests. If ignored these conflicting interests can easily threaten the viability of an energy technology. Therefore, it is important to get to know each actor's main and less predominant aims.

For our method, we are interested in the actors' aims regarding a new energy infrastructure, although this does certainly not imply that aims should only include technical or financial issues. For instance, a concern for the environment may be reflected in an aim to reduce the CO_2 emissions of energy systems. However, for the method to be practical, the number of aims per actor must be limited. Therefore, it is necessary for the actors to attach priorities to the aims. So in case an actor has a long list of priorities, only the first few with the highest priorities are taken into account. At a later stage there is always the possibility of analyzing he effect of including other aims. The next step is then to operationalize the aims by translating them into proper measurable indicators, which will be the topic of the next section.

Setting Indicators

Because most aims are formulated in ambiguous terms and are difficult to measure directly (e.g., a "flexible" infrastructure), we need to find measurable indicators that properly reflect (parts of) the aims of all the relevant actors. These indicators can then be used to assess the impacts of the different technology options. In the literature it is common to make a distinction between technical, financial, economic, environmental, social, and sometimes also political, institutional, and cultural aspects or impacts for each of which indicators should be found. However, since the aims in our method are not determined beforehand (as opposed to most other models), but put forward by the actors, such a distinction is less useful. Moreover, many aims include more than one of the above mentioned aspects, which makes such a distinction rather artificial. Nonetheless, it seems helpful to develop a database that links possible aims to indicators. Users of the method can use this database to come up with the aims that they find important and see which indicators are associated with an aim. The literature mentions many examples of predefined indicators for analyzing the impacts of various technologies. For example, Carpenter (1987, 16) specifies 7 main indicators including employment generation, capital saving, energy saving and efficiency, environmental soundness, socio-culturally and economically appropriate (encompassing compatibility with local tastes and cultures, designed to address context specific needs and constraints, compatible with local purchasing power, and utilization of local raw materials), involvement and participation of women, and finally consistency with other activities in a systems sense. Sometimes these indicators are so vaguely defined that it would be better to speak of 'aims' instead. An example is Van Pelt (1993) who uses only three main aims to assess the suitability of options: efficiency, equity, and sustainability, but these aims need to be converted to become more operational.

Van Pelt (1993, 42-43) mentions three general guidelines which are useful for setting indicators:

1. *Comprehensiveness*
   The set of indicators should be comprehensive in the sense that it covers all relevant aspects, and not just those for which information is easily available.
2. *Independence*
   To avoid double counting (a positive score on one indicator implies automatically a positive score on another indicator), the indicators should be independent.
3. *Limited number of alternatives*
   Van Pelts states that in practice, people can assign meaningful weights (i.e., distinguish priorities) to no more than about eight indicators. Therefore, the number of indicators should be limited. This may require that actors establish a hierarchy of aims whereby the corresponding indicators are divided into sub-indicators (or constituents or attributes).

The indicators allow you to systematically compare the different energy technology options. Each technology will have a specific score on an indicator (the impact). The scores on all indicators (the impacts of a certain option) determine to which extent that option is appropriate. So the indicators form the basis for comparing the energy technology options. The technology options that are available in a certain region result from the available resources and the available technologies, the topics of the next two sections.

Relevant Resource Options

Energy resources include renewable and non-renewable (depletable) resources. Water, wind, the sun, and biomass are all renewable sources although it should be noted that biomass is only renewable if managed in a "sustainable manner" (i.e., given enough time to recover from harvests). Non-renewable energy sources encompass uranium together with the fossil fuels such as crude oil, natural gas, and coal. To determine the relevancy of energy resources we will only look at the following aspects:

- local circumstances such as geographical and atmospheric conditions
- whether a resource is technically exploitable
- whether there exist technologies to convert the resources into the proper energy form

A detailed description of different energy sources and associated energy conversion technologies can be found in for example, Van Beeck (1998), "Characteristics of Waste and Bio-Energy"; Van Beeck (1999b), "Characteristics of Wind Energy" and; Van Beeck "Characteristics of Solar Energy."

Appropriate Technologies

In a given context, only a limited number of technology options are available and not all of them will be relevant. For instance, there is no point in including hydro systems if there is no river nearby. So only the relevant technologies are taken into account in our method. But which of these relevant options are also appropriate? And how, then, do we define appropriateness? In many cases, the main indicator for choosing the "best" technologies has long been –and still is– efficiency. However, there is a growing awareness that pure technical-financial considerations do not guarantee successful adoption of technologies in developing countries. In fact, the large number of failures among projects regarding the introduction of the "best" technologies strengthens the thought that technology choice based upon technical and financial efficiency indicators may not result in the selection of the most viable technologies. As a response, the concept of 'appropriate technology' has been introduced as a means for also incorporating other indicators in order to determine whether a technology is appropriate i.e., viable, or not.

In the literature, two schools of thought can be found with respect to appropriate technology. On the one hand, Appropriate Technology (with capital A and T) is synonym for Intermediate Technology as conceptualized by Schumacher (1975). These technologies are characterized by low capital costs, are labor intensive, and use local materials and labor. The technologies are easy to use, maintain and repair. Another definition is given by McRobie

(1981), who sees Appropriate Technology as a developmental strategy. Technologies satisfying his definition are characterized by low capital costs, satisfy self-expressed local needs, make optimal use of local resources, are easy to understand and access for all social levels, are compatible with user attitudes, values and purposes, are compatible with the environment, are economically self-sustaining, have optimal reliability and dependability, are flexible and adaptable, and promote self-sufficiency.

Through the years, many additional requirements were added. For instance, Carpenter (1987) mentions that in 1979, Chowdhury identified as many as 145 criteria to define Appropriate Technologies, and in that same year Diwan and Livingston commented that "there is no single best definition of Appropriate Technology."

The concept of Appropriate Technology or Intermediate Technology was –and still is– often associated with second rate technologies, especially by developing countries where they should be applied. As a result, the acceptability of those "appropriate" technologies is usually low, although acceptance may be increased if specific local aims and needs are taken into account.

The problem with predefining criteria to which technologies must comply in order to be "Appropriate" is that it places these technologies outside the context in which they are meant to be applied. This is acknowledged by the other school of thought on appropriate technology (see, for instance, Das (1981), Betz et. al. (1984), Carpenter (1987)) The context consists of economic, cultural, social, institutional, environmental, and other factors present in a society or group. Context could thus be referred to as "local circumstances," although this obscures the fact that context plays a key role on national or international levels as well. It is exactly the context that determines which technologies are viable and which are not. From this perspective it makes no sense to preset criteria for appropriate technologies because these criteria must be obtained at the place where the technologies will be applied. This view is also mentioned in *A Decision Making Model for the Selection of Appropriate Energy Technologies in the Caribbean Basin* by Carpenter (1987). According to Long (1980, p. 1), appropriate technology is defined as "… the technology that is appropriate to a particular situation faced by a given group of people, with consideration given not only to economic circumstances and available resources but to value priorities."

In this paper, we adopt the "context" school of thought on appropriate technology, namely that the appropriateness of technologies is determined by the context existing at the place where they are applied. Although the above definition of appropriate technology may seem rather vague (it certainly is much shorter than the one of Appropriate Technology), it would be inappropriate to limit the concept of appropriateness beforehand based upon our preconceived definitions.

So the ultimate aim in our case of local energy planning is to find the most appropriate energy technologies within a given context, where appropriateness is being defined by that same context. As we discussed earlier, our method incorporates the context by including the aims of all the relevant actors

Assessing Impacts of Technology Options

A well-weighed choice for a particular system can only be made if all the relevant alternatives *and* their associated consequences are known and taken into account. Therefore it is important to make an assessment of the relevant impacts associated with the energy technology options. The relevant impacts are the scores of each technology on each of the indicators that were set at a previous step of the method. These scores can be expressed in various units of measure so it is important to ensure that scores of different technologies on one indicator are expressed in a consistent manner. For an easy comparison of the options, the scores should be expressed in quantitative measures as much as possible, preferably of a monetary or physical kind. However, in practice this may not always be achievable due to lack of reliable data or the impossibility of expressing an impact in a quantitative way. Therefore, the method allows for inclusion of qualitative measures, for instance using an ordinal or nominal scale.

The impact assessment results in an overview of how well each technology option scores on each indicator. The next step in the process is then to compare the different technology options for each energy service. This will be discussed in the next section.

Appraising Technology Options

In the appraisal step of the decision making process the question is addressed how to evaluate the impacts of the technology options and how to compare the technology options mutually. Most actors will have a general idea on what for them would still be an acceptable impact. This critical score on an indicator is the actor's criterion to either reject or accept an option. It may be that during the impact assessment an indicator is used that does not reflect any aims of a particular actor. In such a case that actor does not have a criterion for this indicator, although generally, an actor might reject extremely adverse indicator scores even though that indicator did not reflect any of that actor's aims at first. This is then a result of learning processes that take place during the decision making process through interaction with other actors and the gathering of information.

Usually, the actors will have different criteria for an indicator, reflecting their differences in (priorities of) aims. Sometimes, these differences can lead to conflicts, which can seriously hamper the decision process. Therefore, it is helpful to look for potential conflicting interest beforehand so that a clear overview is obtained and an adequate response can be determined directly. It must be said, though, that overcoming conflicts depends for a large part on the willingness of the actors to cooperate in negotiations and to make concessions.

If an actor wants to make the appraisal step more explicit, it can choose to use an appraisal method. Appraisal methods facilitate the comparison of a limited number of alternatives and rank these alternatives according to a preset criterion (e.g., lowest costs, highest output, lowest CO_2 emissions, etc.). A well-known and widely applied appraisal method is Cost Benefit Analysis (CBA). CBA was originally developed for industrial market economies using market prices but has also frequently been applied by many governments, institutions, and other organizations in both developed and developing countries. As a consequence, much experience has been gained in applying the technique. For a detailed discussion of CBA see, for instance, Little and Mirrlees (1974), Squire and Van der Tak (1975), and Kirkpatrick and Weiss (1996).

The CBA focuses on financial or economic[4] efficiency and involves the comparison of direct costs and benefits associated with the alternatives. The costs and benefits are all expressed in a common monetary unit and the alternative with the highest net benefit is chosen. For non-market economies or distorted economies, shadow prices can be used. The outcome of the analysis is usually presented in the form of the Net Present Value (NPV) or the Internal Rate of Return (IRR), expressing the discounted overall net benefit (or cost). The discount rate, used to discount future benefits and costs to today's values, plays a crucial role in the appraisal process. The higher the discount rate, the less weight is given to the long-term effects of an alternative. Note that economic models (or any other models) can not tell us which discount rate is most appropriate in a given situation, this is an arbitrary choice we must make ourselves.

A method similar to economic CBA is the Effects Method (EM), predominantly used in French speaking countries. Basically, it is interchangeable with economic CBA although Franck (1996) argues that EM and economic CBA do not have the same goals, nor do they use the same information or answer the same questions, and therefore in some cases one of the two may be more adapted.

The Cost Effectiveness Analysis (CEA) –a derivative of CBA– is used if the costs can be valued in monetary terms, but benefits cannot. The CEA analyzes and compares the costs of different manners to achieve the same result. This has the advantage that benefits do not have to be specified or made explicit. This is especially useful in cases where benefits are uncertain or cannot be expressed in a monetary value easily, such as a reduction of CO_2 emission levels or the conservation of a certain species. The option with the lowest costs is chosen.

The drawback of CBA and related methods is that they can only include aspects in the analysis, which are expressed in monetary values. Other aspects are not adequately addressed. The result is that many environmental and social impacts and equity issues are not satisfactory taken into account[5]. Attempts have been made to value these impacts, for instance by using the concepts of Willingness to Pay (WTP) or the Willingness to Accept (WTAC). The concept of WTP or WTAC is applied in appraisal methods such as the Contingent Valuation Method (CVM) to convert individuals' behavior and aims for non-market goods or services into a monetary value. Nonetheless, there

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[4] The difference between financial and economic efficiency lies in the fact that "financial" refers to the profitability from a private investors' point of view, while "economic" refers to the welfare of the society as a whole. Economic analyses are usually performed by governments since the latter are the most designated entities to look after the society's welfare. However, this does not imply that governments always let economic benefits prevail over financial ones.

[5] In theory, equity considerations could be addressed using "Social CBA" but according to Van Pelt (1993, 5) this technique appears to be rather inaccessible in practice and requires an enormous amount of data. This is probably the reason why SCBA is not yet applied on a large scale.

are several methodological problems associated with this way of expressing impacts in monetary values (see, for example, Dorfman (1993), and Hanley e.a. (1997)).

Another drawback of CBA (and related) methods is that the valuation of changes in the distribution of benefits and costs among the members of a society can only be done through the calculation of monetized costs and benefits if certain (moral) philosophical viewpoints are discarded. This makes the equity issue a matter of ethics just like the choice of the discount rate. This implies that the CBA methods cannot determine who is the right person, group, or society to do a valuation, nor can they determine what actions are appropriate. In that case, the equity and discounting problems can only be solved by establishing certain ethical rules to which everyone complies, or through negotiation and social consensus.

A method that offers more flexibility when including other aspects is Multi-Criteria Analysis (MCA). Van Pelt (1993, 5) states that until now, MCA has mainly been applied in industrialized countries and that experience in developing countries is low. Applications for selecting energy systems are even scarcer, but Georgopoulou et. al. have done some research on this subject in Greece in 1997 and 1998.

There exist many types of MCA techniques. A general characteristic of the MCA techniques is that they have a much greater flexibility with respect to indicators and data requirements than CBA or related methods. MCA methods can deal with quantitative as well as qualitative information[6]. Van Pelt (1993, 61) states that MCA can encompass any policy-maker’s objective, account for conflicting interests in society, and is especially appropriate in cases where more alternatives are compared. So local cultural values, as well as important qualitative social, environmental, or other aspects can be taken into account through MCA. The analysis may also include a CBA – financial or economic– as one of the indicator. Where CBA uses prices to compare the alternatives, MCA uses a weighting system that is based on the relative priorities of the energy planners or any other actors.

For the decision process of local energy planning only the discrete MCA methods are relevant[7] because these are applicable in cases where there is a limited number of alternatives, such as in energy planning.

As a drawback of discrete MCA methods, Van Pelt states that the internal logic may be difficult to comprehend by people with a non-technical background because of the complicated structure. Also, there are some methodological problems.

The choice for an appraisal method depends on the aims that are included in the analysis. If an actor decides to use an appraisal method and has set high priority to a qualitative indicator, the use of an MCA method seems appropriate. Note that if actors each use a different appraisal method, the outcomes of each method cannot be compared easily.

Evaluation of the Outcome & Selection of an Energy System

After the appraisal step, each actor will have a ranking of energy systems from most to least appropriate in a region. However, these rankings will usually differ so the outcomes need to be evaluated before a mutually supported selection of energy technologies can be made. During the evaluation step actors can adjust their (priorities of) aims or analyze variations on the technology options. If changes are made, the appraisal step and sometimes also the impact assessment need to be repeated, after which the altered outcomes must be evaluated once more. In the situation of several actors having different rankings, negotiations and compromises are usually necessary to come to a final selection of energy technologies. Also, this step in the process can be used to perform a sensitivity analysis in order to analyze the effects of small changes in the parameters of the models.

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6 Van Pelt (1993, 14) states that there are three groups of MCA techniques: one group that can deal with quantitative data only, one that requires qualitative data, and the last group that can deal with quantitative data and qualitative data simultaneously. It is the last group that this paper focuses on.

7 As opposed to the continuous methods (such as multi-attribute utility functions method, multiple criteria linear programming, and multiple goal programming) which involve rather complex techniques (see Van Pelt (1993, 40).

Limitations of the Method

The method described in this paper is only suited for providing support in specific cases and is therefore limited in its applicability. The limitations of the method include:

- The method does not predict the future, nor does it decide for the energy planner which action is good or best.
- Although the method supports in selecting the most appropriate energy systems at the local level, this does not imply that the outcome is automatically most appropriate at the national level as well. For successful implementation it is required that the outcome is in compliance with national policy and thus, possible options should always lie within the regulatory framework of the national government.
- No insight is given in consequences of policy measures. The focus is only on the selection of the most appropriate energy systems.
- The method has an engineering approach in the sense that the analysis takes place at the local level and allows for a detailed representation of technologies. However, no insight is given in the interactions between the different sectors of the economy. The focus is restricted to the energy sector at the local level.
- The outcomes of the method are case specific and cannot easily be generalized. However, the method itself is generally applicable.
- The local decision making process does not necessarily lead to economically or technically optimal outcomes with respect to the energy infrastructure. This is due to the fact that many actors are involved which may have different interests and aims. However, the method will help select the most appropriate energy system in a given context, and the viability of the selected system will likely be high when implemented.

Other limitations will be examined through the use of case studies, which will be discussed in the next section.

The Significance of Case Studies

The new method presented in this paper is based on a literature review as well as interviews with experts in the field. However, for a method to be practical it is essential that case studies are used to gain experience in application, to further examine the limitations of the method's applicability, and –if necessary– to adjust the method. Therefore, the method will be applied to two case studies of which one is a region in Costa Rica, and one is the region Noord-Brabant (a province in the Netherlands). Although Noord-Brabant has one of the fastest growing economies in the Netherlands, it can hardly be regarded as a region in a developing country. However, Noord-Brabant will be used as a first test case for the applicability of the method because information is more readily available in this case. Also, we are interested in comparing the results of the two regions. Besides for testing the applicability of the method, the case studies are used to specify the requirements of the models associated with the method.

It is very common for energy planning decision processes to take more than one year. Due to time constraints we are not able to test the method by applying it to an entirely new case and proceed through the whole process. Therefore, the method will be applied to cases that already have taken place –at least for a large part- in order to analyze how the steps in the method compare with reality. So the method is not tested in the strict sense of the word.

Conclusions

Energy planning is an essential tool in the economic development of industrialized as well as developing countries. Energy planning in this paper is restricted to the selection of new energy systems for the production of proper energy forms in order to meet increased energy demand. This demand is actually the desire for certain energy services, which are the starting point of the new decision support method for local energy planning presented in this paper. In the decision making process concerning energy planning at the local level it is important to include context-related issues because the context determines for a large part the viability of the technologies or systems used. The context, in turn, is represented by the aims of the relevant actors, which are translated into measurable indicators to compare the different options. The impact assessment must allow for inclusion of all the indicators, either quantitative or qualitative in order to find the most *appropriate* technology for a region rather than the technically best or economically most optimal one. Appropriateness is defined by the context and is thus case specific, but the framework described in this paper is generally applicable within the given limitations. Note that the new method described in this paper is a decision support tool, implying that it does not decide for the energy planner which actions to take. The ultimate decision must be made by the planners themselves.

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